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ВИБІР СТРАТЕГІЇ ДЛЯ ОПТИМАЛЬНОГО МЕТОДУ ШТУЧНОГО ПІДЙОМУ (НА ПРИКЛАДІ НОВОТРОЇЦЬКОГО РОДОВИЩА, УКРАЇНА)

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SELECTION STRATEGY FOR THE OPTIMAL ARTIFICIAL LIFT METHOD (ON THE EXAMPLE OF NOVOTROITSK FIELD, UKRAINE)

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ABSTRACT

The relevance of paper. Artificial lift is a method used to lower the producing bottomhole pressure on the formation to obtain a higher production rate from the well, adding up to the different kinds of artificial lifts with their own characteristics and restrictions, with the understanding of the importance of selecting the right artificial lift for each type of well with it is own reservoir and fluid characteristics. Currently, against the background of depletion of Ukrainian oil and gas fields, the choice of necessary method of artificial lift is very important.

The purpose of article is selecting upmost efficient artificial lift system at Novotroitsk field, based on the limitations, advantages and disadvantages of each type of artificial lift system, along with reservoir characteristics and fluid phase behavior.

The object of study is process of artificial lift at Novotroitsk oil-gas-condensate field.

The tasks of paper is combination of methods by expert programs, technical surface and infrastructure considerations, to create an analysis to screen candidate artificial lift systems, and then to select one for implementation.

The research methodology that was used is PIPESIM software with the analyzing of the different parameters including reservoir characteristics and fluid phase behavior and their effect on inflow performance relationship were investigated to study the effectiveness of the artificial lift systems.

Keywords: production indicators, artificial lift, PIPESIM, oil recovery, field.

Introduction. Oil production from reservoirs usually occurs by natural flow of the fluid out of the formation. This oil recovery is called primary recovery, where the production is solely controlled by the natural energy of the formation. However, after some times of production reservoir pressure declines, which causes a decline in oil production rate. Thus, regaining the reservoir pressure to enhance oil production is of great importance. Artificial lift (AL) methods as one of the best methods of oil recovery when reservoir pressure declines have been implemented for decades. This is proved in the papers of H.Beggs, K. Ebrown, Dale-Beggs, J. V.Vogel, W. D.McCain, P. Oyewole and others [1-8].

The reservoir pressure of one of the oil fields in Ukraine (Novotroitsk) has been dropped to a level where no natural fluid flow occurs form the reservoir. AL methods have been proposed to compensate the

natural pressure of the reservoir and ease the petroleum production from the reservoir. PIPESIM software was used to study the effectiveness of the AL systems. Different parameters including tubing diameter, injected gas rates, and injection depth and their effect on inflow performance relationship (IPR) were investigated. The simulation results showed that natural energy of the reservoir is not sufficient for producing oil. Thus, progressive cavity pump (PCP) as of the best methods of increasing the production rate in this field could be implemented successfully.

Problem Statement. The production rate or deliverability of a well can often be severely restricted by the performance of only one component in the system if the effect of each component on the total system performance can be isolated. The system performance can be optimized in the most economical way. Past experience has shown that large amount of money has been wasted on stimulating the formation when the well's producing capacity was actually been restricted because the tubing or flow line was too small. Another example of errors in completion design is to install tubing that is too large. This often happens on wells that are expected to produce at high rates. This practice not only wastes money on oversized equipment, but also tubing that is too large can actually reduce the rate at which a well will flow. This can cause the well to load up with liquids and die, which necessitates the early installation of artificially lift equipment or compression.

However, continuous discovery of new fields in combination with the optimization of production on the existing ones has become more essential than ever. The concept of production optimization was not introduced from the beginning of the oil age. Ever since, the progress in technology has provided the tools to Petroleum Engineers to exploit the oilfields as efficiently as possible and maximize recovery factors.
With rising global demand on oil and gas products, as well as producing and lifting oil and gas in an economical way, there is no doubt that the development of such non-renewable resources is at an intimidating phase. Unfortunately, for the unconventional wells with high decline rates between 50 to 80% in the first year, the outdated approach of lift selection strategy is insufficient to manage unconventional wells in an effective way. Unconventional well problems are challenging the boundaries of existing artificial lift systems, which expectedly affecting the economic feasibility of unconventional oil and gas production.

The importance of choosing the best method for the unconventional well, by considering its location, depth, estimated production, reservoir properties, and other factors, are discussed in this paper which reviews methods for selecting the appropriate artificial lift method depending on the situation. Often a combination of these methods may be used - one to screen candidate systems, then one for selection.

Artificial lift is a method used to lower the producing bottomhole pressure (BHP) on the formation to obtain a higher production rate from the well. This can be done with a positive-displacement downhole pump, such as a beam pump or a progressive cavity pump, to lower the flowing pressure at the pump intake. It also can be done with a downhole centrifugal pump, which could be a part of an electrical submersible pump (ESP) system. A lower bottomhole flowing pressure and higher flow rate can be achieved with gas lift in which the density of the fluid in the tubing is lowered and expanding gas helps to lift the fluids. Artificial lift can be used to generate flow from a well in which no flow is occurring or used to increase the flow from a well to produce at a higher rate. Most oil wells require artificial lift at some point in the life of the field, and many gas wells benefit from artificial lift to take liquids off the formation so gas can flow at a higher rate.

The paper describes the most effective artificial lift systems applicable during specific period of a well life. An artificial lift system is phased over the life of the well based on current and expected production rate requirement and lift method capability. The lift systems were further evaluated based on several criteria through elimination and selection techniques.

As well as this paper includes a case study of Novotroitsk field oil wells. In the coming years, there will be sharp decreases in well production (Figure 1), so these studies are very important. The lift evaluation process, which includes a combination of reservoir fluid properties, and well performance impact were used to analyze the effect of various artificial lift selection options on the life of well value.

The Purpose Of Article is selecting upmost efficient artificial lift system at Novotroitsk field, based on the limitations, advantages and disadvantages of each type of artificial lift system, along with reservoir characteristics and fluid phase behavior.

The Tasks Of Paper is combination of methods by expert programs, technical surface and infrastructure considerations, to create an analysis to screen candidate artificial lift systems, and then to select one for implementation.

Results And Discussion. The analysis of the well as system of components was introduced in mid 50s by Gilbert. The main objective of such analysis is to combine the characteristics of each component in order to estimate production rates and optimize the system's productivity. Initial reservoir pressure is generally large enough to lift the reservoir fluids up to the surface. As production continues, the pressure becomes gradually lower and the liquid rates are deteriorated. For this reason, the principles of fluid flow in porous media and pipelines were thoroughly examined. As the produced fluids travel from the reservoir to the surface facilities, a significant amount of pressure is wasted due to a series of factors. The optimization of these factors, so that the lowest pressure drop possible in a well occurs, is the reason behind the development of system analysis or else Nodal Analysis. The main purpose of this analysis is the prediction of achievable fluid production rates from reservoirs with specified production string characteristics. The main goal behind this technique and optimization methods is to optimize

the well so that the maximum possible flow rates which could be achieved by the reservoir would not be restricted due to the design of the well.

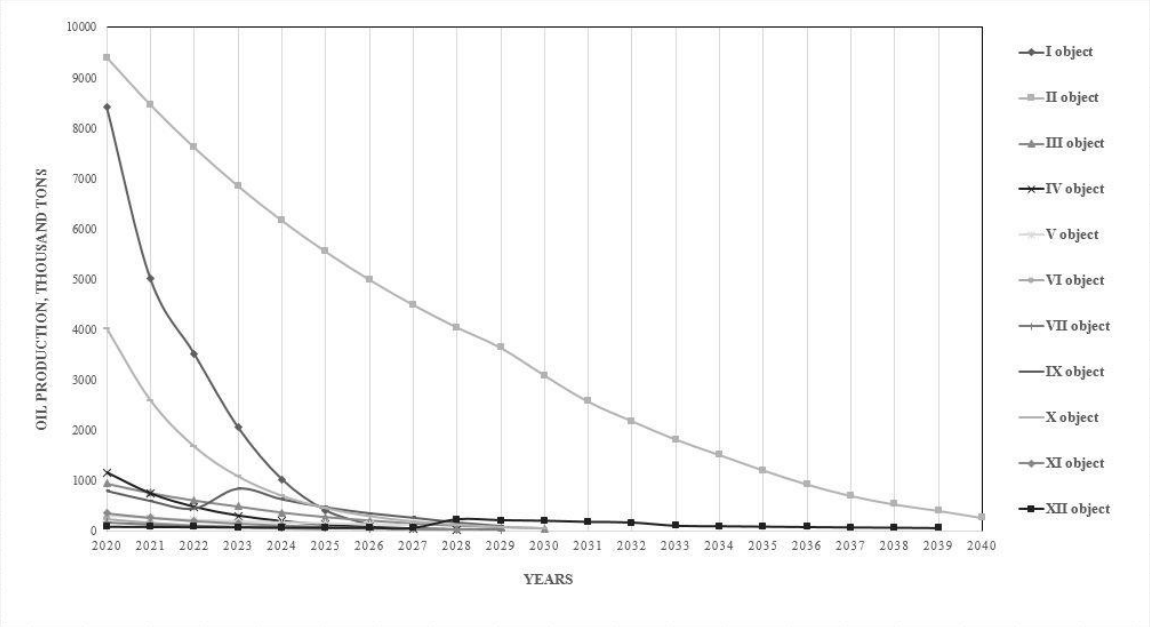

Fig.1. Perspective oil production by objects of Novotroitsk field

Artificial lift elimination and selection

There are next the most popular AL methods now: gas lift system, electrical submersible pump, rod & beam pump, hydraulic pump, plunger lift, progressive cavity pump (Figure 2).

As it is well known, there is a wide range of artificial lift systems (ALS) available for oil and gas application. The requirement to eliminate and select the best artificial lift method and strategy for the life of the well cannot be over-emphasized.

Yearly, the industry loses billions of dollars in both revenue loss and lift conversion or inefficient lift performance and failure expenses due mainly to improper artificial lift selections. The current major requirement to lower lifting cost for unconventional oil to compete favorably with conventional oil lifting cost is to renew focus on artificial lift selection in the basins. Several important factors need to be considered in artificial lift elimination and selection process (Lea, Nickens, Wells, 2008); (Oyewole, Lea, 2008).

Although there has been discussion regarding ALS selection criteria over the last 40 years as the industry has involved, it is important to review some of the most important criteria and considerations when it comes to selecting an ALS (Clegg, Bucaram & Hein, 1993). The selection criteria include but are not limited to the following:

- Based on the mechanical limit;
- Based on advantages and disadvantages;
- Selection through expert programs;
- Selection by comparison of Net Present Value (NPV).

Based on the experience of companies using the different ALS, the conjunction of these methodologies is common practice, so more than one methodology is usually used. Table 1 provides a summary of the considerations that encompass the criteria listed above.

Table 1 – Criteria consideration

Reservoir	**Well**	**Others**	**Economic**
Productivity (static pressure, P_{wf})	Location (on-shore, off-shore)	Flexibility	Initial investment
Reservations involved	Geometry	Energy	Operating cost
Fluid type (% of phases, viscosity, solid content, fluid aggressiveness)	Diameter	Products and services	Services cost
Gas oil ratio (GOR)	-	Availability	Re-sale
Bottom temperature	Completion	Previous experience	-
-	Depth	Surface disturbance	-
-	Temperature	Visual impact	-

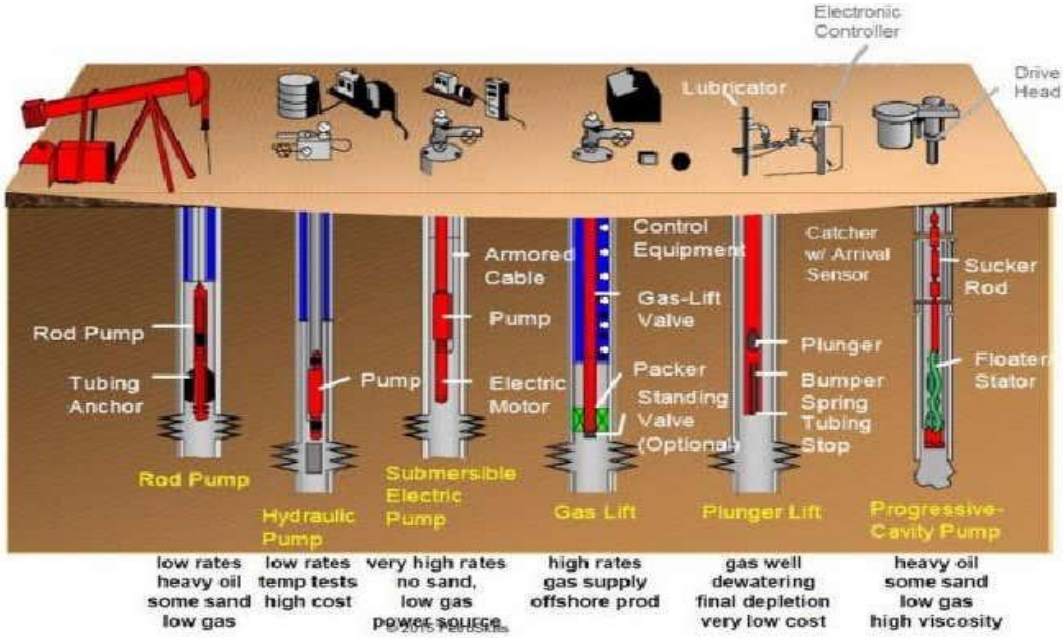

Fig. 2. Common artificial lift methods

This paper will present an artificial lift selection strategy based on some of the criteria that results in the change of the behavior of flow in oil wells. More than one methodology will be used to eliminate the non-compatible artificial lifts based on their specific advantages and disadvantages as well as their overall comparison based on their limitation and usage for each specific criterion.

Each artificial lift method has it is own limitation and usages to each specific criterion. Temperature, gas/water handling, production rate range and many other criteria are diverse between each methods of artificial lifts. Which means not every artificial lift method is a viable option to use for an unconventional well; some of the criterions can be illustrated within Table 2 below.

By the consideration of such list of limitation and usages of artificial lift systems, the most apparent non-compatible artificial lift systems can be excluded for specific oil wells.

Such elimination process of the non-compatible artificial lifts, will usually lead to a multiple choice of compatible artificial lift systems. The selection process of the most compatible one can be obtained by analyzing the reservoir characteristics and the fluid phase behavior.

By highlighting the GOR variation in a specific basin, it provides additional layer of complexity to defining artificial lift strategy to maximize the asset value. Definitely, this is the main reason why – one artificial lift type strategy, is not always an effective strategy.

Simulation study

In order to perform the optimization study, PIPESIM software was used. This software is capable of determining optimum production scenarios during artificial lift activities. The required data such as production rate data, average reservoir pressure, bottom hole flowing pressure, and well profile data were used as input data. The vertical multiphase flow correlation and fluid properties were utilized to determine production rate.

The area of research was Novotroitsk oil-gas-condensate field that is located in the Lebedyn district of Sumy region of Ukraine. Tectonically, the field is located in the central part of northern riparian zone of Dnipro-Donetsk basin, within the Novotroitsk ledge of foundation.

According to the results of industrial geophysical research and testing of wells of Novotroitsk field, 12 operating objects in productive horizons of the Upper Visean sediments have been established:

- I object – horizon V-23 in block I (developed by wells 37, 205);
- II object – horizon V-23 in block IIa (developed by wells 13, 40);
- III object – horizons V-23 + V-22n in block IIb (developed by wells 6, 16, 30, 34, 55);
- IV object – horizon V-22n in block III (developed by well 200);
- V object – horizons V-16v_2 + V-16n_1 + V-19 + V-20 in block IIa (developed by wells 31, 106);
- VI object – horizon V-18s block IIa (developed by well 103);
- VII object – horizons V-15v, V-15s in block VIII and horizons V-16v_2 + V-16n_1 +V-16n_2 in block I (developed by wells 32, 102);
- VIII object – horizons V-15n + V-16n_1 in block III (developed by well 201);
- IX object – horizon V-16v_1 in block I (developed by well 38);
- X object – horizon V-16v_1 in block V (developed by wells 14, 41);
- XI object – horizon V-15n in block IIb (developed

by well 10);

- XII object – horizons V-15v + V-15n in block IIa (developed by well 33).

Currently, the Novotroitsk oil and gas wells are operated by mechanized methods: jet pumps and gas lift and also by a fountain method. Technical and technological indicators of well operation in accordance with approved technological regimes.

The lack of detailed reservoir characteristics and fluid phase behavior input in many artificial lift strategies is unexplainable. Perhaps! This might be due to lack of understanding its value in artificial lift selection strategy. It may also be due to lack of data.

This part demonstrates how reservoir and fluid properties provides a deciding input into the artificial lift selection strategy.

The geological depositional environment, reservoir and fluid properties, not only varies by formation with depth, strong regional variation is observed with distance in the same formation.

A "3-well evaluation" is presented for artificial lift selection strategy that is driven mainly by fluid properties. Table 3 shows pertinent PVT data of the wells.

Table 2 – Summarized artificial lift limitation

	Electric Submersible	**Gas Lift**	**Hydraulic Jet**	**Rod Lift**	**Progressing Cavity**	**Hydraulic Piston**	**Plunger Lift**
Operating Depth	1,000 - 15,000 TVD	5,000 - 15,000 TVD	5,000 - 18,000 TVD	100 - 16,000 TVD	2,000 - 6,000 TVD	7,000 - 20,000 TVD	8,000 - 19,000 TVD
Operating Volume	100 - 30,000 BPD	200 - 30,000 BPD	100 - 10,000 BPD	5 - 5000 BPD	5 - 4500 BPD	10 - 1,000 BPD	1 - 300 BPD
Operating Temperature	100 - 400 F	100 - 400 F	100 - 500 F	100 - 500 F	75 - 250 F	100 - 500 F	130 - 500 F
Corrosion Handling	Good	Good to Excellent	Excellent	Good to Excellent	Fair	Good	Excellent
Gas Handling	Fair to Good	Excellent	Good	Fair to Good	Good	Fair	Excellent
Solid Handling	Fair to Good	Good	Excellent	Fair to Good	Excellent	Poor	Fair
Fluid Gravity	>10 API	>15 API	>8 API	>8 API	<35 API	>8 API	GLR 300 SCF/ BBL
Servicing	Work over or Pulling unit	Wire line or Work over Rig	Pump Up or Wire line	Work over or Pulling Unit	Work over or Pulling Unit	Pump Up or Wire line	Well-head Catcher or Wire line
Prime Mover	Electric or Multi Cylinder	High Pressure Gas	Electric or Natural Gas	Gas or Electric	Gas or Electric	Electric or Natural Gas	Wells Natural Energy
Offshore Application	Excellent	Excellent	Excellent	Limited	Good	Good	N/A
Overall System Efficiency	35% - 50%	10% - 30%	10% - 30%	45% - 60%	40% - 70%	45% - 55%	N/A

Table 3 – Wells characteristics in the horizon V-23 at the Novotroitsk field

No. of wells	**Well No. 13**	**Well No. 55**	**Well No. 205**
Reservoir fluid type	Oil and gas	Oil and gas	Oil and gas
Vertical depth to perforations (m)	3293,5	3303,5	3382,5
Casing size (mm)	140	168	140
Tubing size (mm)	73	73	73
Water cut (%)	80,25	82,48	61,14
Oil gravity API	46,7	39,3	34,3
Gas gravity (mg/cm^3)	0,743	0,841	0,745
Water gravity (g/cm^3)	1,137	1,189	1,181
Produced GOR (m^3/ton)	64	1636	93

Produced GLR (m^3/ton)	12,64	287	37,47
Bubble point (MPa)	26	22,2	26
Static reservoir pressure (bar)	235	226	242
Reservoir temperature (^{0}C)	82	80	91
Production oil volume (bbl/day)	82,399	71,706	45,6654
Bottom hole pressure (bar)	205	196	212
Production gas volume (thousand m^3/day)	0,8	18,6	0,7
Oil formation volume factor (Bo)	1,7	1,43	1,7

Table 4 – The obtained results after the simulation of different AL methods

Para-meters	**Name of the AL methods**														
	Gas Lift			Hydraulic Jet			**Progressing Cavity**			Electric submersible pump			Injection of hot condensate into annulus		
	13	55	205	13	55	205	**13**	**55**	**205**	13	55	205	13	55	205
Production oil volume (bbl/ day)	85	75	49	86	75	50	**96**	**92**	**61**	84	78	43	85	75	51
Production gas volume (thousand m^3/day)	0,8	19,6	0,9	0,9	19,6	0,9	**1,0**	**22,9**	**1,0**	0,8	19,8	1,0	0,9	19,9	1,0
GOR (m^3/ton)	95	1790	130	70	175	99	**90**	**195**	**110**	69	165	111	85	202	130
Produced GLR (m^3/ton)	14	295	42	18	302	42	**22**	**312**	**52**	20,2	295	42	14	295	43
Bottom hole pressure (bar)	190	182	203	201	192	202	**180**	**178**	**190**	199	191	204	202	186	203
Water (%)	85	87	69	82	84	68	**84**	**85**	**68**	88	89	70	84	88	66

Table 5 – Comparison results between AL methods for well No. 13

Artificial lift methods	**Production gas volume (thousand m^3/day)**			**Production oil volume (bbl/day)**		
	Initial volume	After implementation volume	Difference %	Initial volume	After implementation volume	Difference %
Gas Lift	0,8	0,82	0,25	82,399	85,3	0,35
Hydraulic Jet	0,8	0,86	0,47	82,399	86,25	0,457
Progressing Cavity pump	**0,8**	**0,95**	**13,7**	**82,399**	**96,36**	**14,49**
Electric submersible pump	0,8	0,88	6,9	82,399	84,45	0,253
Plunger Lift	0,8	0,89	7,9	82,399	85,33	0,34

Table 6 – The production results for PCP method before and after

Progressing Cavity Pump	**Production gas volume (thousand m^3/day)**			**Production oil volume (bbl/day)**		
	Initial volume	After implementation volume	Difference %	Initial volume	After implementation volume	Difference %
Well No. 13	0,8	0,95	18,75	82,399	96,36	14,49
Well No. 55	18,6	22,85	22,85	71,704	91,56	27,69
Well No. 205	0,7	0,95	25,5	45,664	60,63	32,77

Conclusions. In the article the actual problem of oil and gas engineering was solved – artificial lift strategy for big Ukrainian (Novotroitsk) field was determined via PIPESIM software. It is required to maximize oil and gas assets value firstly by the process of elimination and comparison of the limits and usages of artificial lift systems and secondarily by the simulation of the optimum production scenarios during artificial lift activities by the usage of expert software analysis selection.

The sensitivity analysis on various liquid flow rates with the utilization of the multiphase flow correlation, fluid properties and reservoir characteristics, gave us an insight of the optimum artificial lift system to maximize the assets value, the selection of the optimum artificial lift throughout the results is considered by the higher percentage of increasing of oil and gas production volume for each well being analyzed as shown below:

- for Well No. 13, an increase in production by 18,75% and 14,49% of gas and oil respectively;
- for Well No. 55, an increase in production by 22,85% and 27,69% of gas and oil respectively;
- for Well No. 205, an increase in production by 25,5% and 32,77% of gas and oil respectively.

These results have been perceived after implementation of progressive cavity pump (PCP) as the optimum artificial lift. Other artificial lift systems that have been analyzed all revealed a less percentage of increased production with respect to the PCP.

Thus, we can conclude that the implementation of PCP as the optimum artificial lift for the studied wells will maximize the assets value in the most lucrative way.

REFERENCES / СПИСОК ЛІТЕРАТУРИ

1. Beggs H. (2008), Production Optimization Using Nodal Analysis, Oil & Gas Consultants, 2nd edition.
2. The technology of artificial lift methods. Volume 1 by Kermit Ebrown.
3. Production Optimization Using Nodal Analysis by Dale-Beggs.
4. Vogel, J. V. (1968), Inflow Performance Relationships for Solution-Gas Drive Wells. J. Pet. Technol. 20 (1): 83-92. SPE 1476-PA.
5. Production Technology (2011), Heriot Watt University, Institute of Petroleum Engineering, 2011.
6. McCain, W. D. (1990), The Properties of Petroleum Fluids. 2nd ed. Tulsa, OK: Pennwell.
7. Peter Oyewole (2016), SPE, BOPCO L.P. Artificial Lift Selection Strategy to Maximize Unconventional Oil and Gas Assets Value, SPE-181233-MS.
8. https://aa33a729c4d7eb75abd81ae00f793baf04b21219d7316d3d0fd8.ssl.cf3.rackcdn.com/apergy-files/Artificial-Lift-Selection-Process-NEW.pdf.

ABSTRACT (IN UKRAINIAN)

Актуальність роботи. Штучний підйом – це метод, що застосовується для зниження вибійного тиску в свердловині, щоб отримати більш високу швидкість видобутку зі свердловини. Існують різні види штучних підйомів із власними характеристиками та обмеженнями, при цьому важливий підбір правильного штучного підйому для кожного типу свердловини з власними пластовими та флюїдними характеристиками. Наразі на тлі значного виснаження українських нафтогазових родовищ вибір правильного методу штучного підйому є дуже актуальним.

Мета статті – вибір найефективнішої системи штучного підйому на Новотроїцькому родовищі на основі обмежень, переваг і недоліків кожного типу штучних підйомних систем, а також характеристик резервуара та фазового режиму.

Об'єктом дослідження є процес штучного підйому на Новотроїцькому нафтогазоконденсатному родовищі.

Завдання роботи полягають в поєднанні методів за експертними програмами, технічної поверхні та інфраструктурних міркувань, щоб виконати аналіз для показу систем-кандидатів штучного підйому, а потім обрати один для впровадження.

Методологія досліджень – програмне забезпечення PIPESIM з аналізом різних параметрів, включаючи характеристики резервуарів та поведінку фази рідини та їх вплив на співвідношення продуктивності припливу.

Ключові слова: показники видобутку, штучний підйом, PIPESIM, вилучення нафти, родовище.

ABSTRACT (IN RUSSIAN)

Актуальность работы. Искусственный подъем – это метод, который применяется для снижения забойного давления в скважине, чтобы получить более высокую скорость добычи из скважины. Существуют различные виды искусственных подъемов с собственными характеристиками и ограничениями, с пониманием важности подбора правильного искусственного подъема для каждого типа скважины с собственными пластовыми и флюидного характеристиками. Сейчас на фоне значительного истощения украинских нефтегазовых месторождений выбор правильного метода искусственного подъема очень актуально.

Цель статьи – выбор наиболее эффективной системы искусственного подъема на Новотроицком месторождении на основе ограничений, преимуществ и недостатков каждого типа искусственных подъемных систем, а также характеристик резервуара и фазового режима.

Объектом исследования является процесс искусственного подъема на Новотроицком нефтегазоконденсатном месторождении.

Задачи работы заключаются в сочетании методов по экспертным программам, технической поверхности и инфраструктурных соображений, чтобы выполнить анализ для показа систем-кандидатов искусственного подъема, а затем выбрать один для внедрения.

Методология исследований – программное обеспечение PIPESIM с анализом различных параметров, включая характеристики резервуаров и поведение фазы жидкости и их влияние на соотношение производительности притока.

Ключевые слова: показатели добычи, искусственный подъем, PIPESIM, извлечение нефти, месторождение.

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